National Park Service
U.S. Department of the Interior

Natural Resources Stewardship and Science Directorate

Climate Change and Impacts to Resources around the Great Lakes
Talking Points

Climate Change Talking Points NPS/NRSS—2007/001

The following talking points, or messages, may be useful to park staff when framing interpretive programs, providing interpretive services, and responding to general questions and media inquires about climate change and its impact on park resources in the Great Lakes region. They also provide helpful information to consider in the development of sustainability strategies and long-term management plans.

Interpreting this topic raises the visitors' awareness about our changing climate and its impacts. Park audiences will understand and participate in efforts to adapt to the changes and to minimize the human contribution. National Parks connect us to our collective heritage, both natural and cultural. In the face of "unequivocal" climate change, parks can help everyone make choices for a sustainable way of life.

Au Sable Light Station, Picture Rocks NL. Photo by Chris Case

The points are organized according to the following types of impacts:

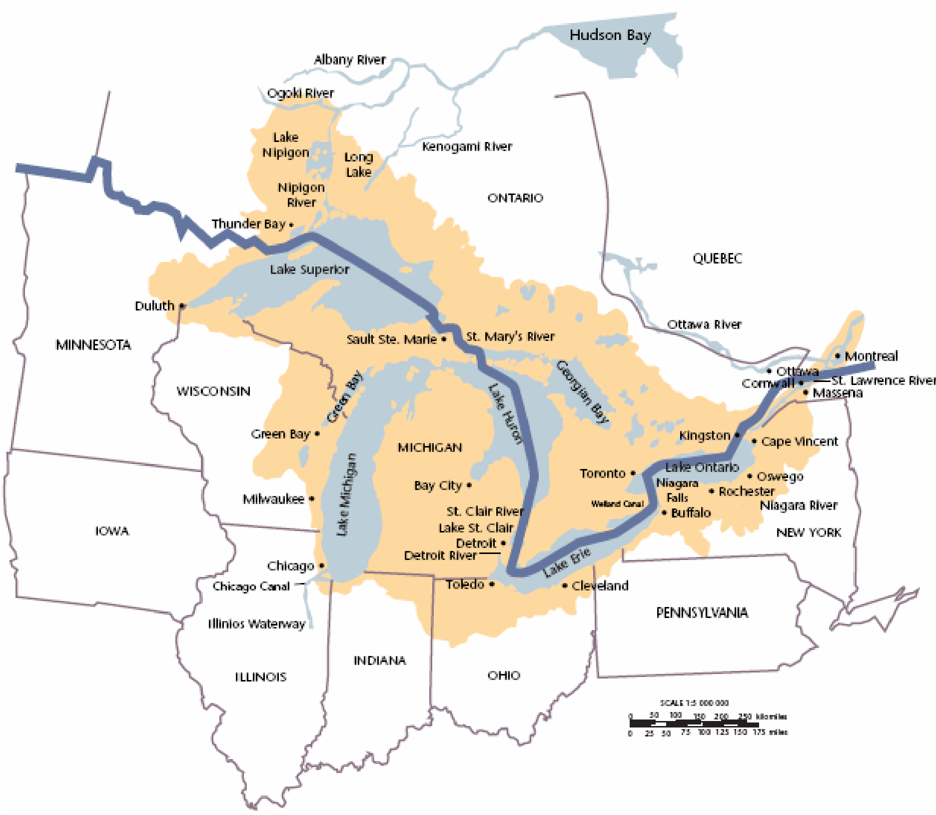
I. temperature
II. water cycle (including ice)
III. vegetation
IV. wildlife
V. disturbance and landscape modification
VI. the park experience
VII. what parks and their partners can do about it

Messages are grouped according to the type of scientific knowledge that backs them. While all of the talking points are informed by science, some statements are primarily based on factual records while others rely more on scientific reasoning and models. You can think of this as a "confidence level" for the messages. For example, statements under:

- "what scientists know" are based on measurable data and historical records. These are more or less factual statements;
- "what scientists think they know" messages represent a step beyond simple facts and require some level of reasoning or critical thinking to derive. They result from projected trends, climate or ecosystem models, or empirical relationships (statistical comparisons) of existing data, and;
- "what scientists think is likely" are based on knowledge of climate and ecosystem processes but have a higher degree of inference or deduction associated with them. In some cases, these are based on preliminary conclusions from scientific research.

This document has been created using data for the Great Lakes watershed shown below and nearby parks. This analysis is most useful for the following US national park units within the Great Lakes region, though it should be of interest to other park units in the Midwest Region as well:

- Apostle Islands National Lakeshore
- Indiana Dunes National Lakeshore
- Isle Royale National Park
- Keweenaw National Historical Park
- Perry's Victory and International Peace Memorial
- Pictured Rocks National Lakeshore
- Sleeping Bear Dunes National Lakeshore
- Voyageurs National Park



The Great Lakes basin (orange) encompasses more than 308,000 square miles of the North American heartland and contains the largest single concentration of liquid fresh water on the planet (from Kling et al. *2003).*

First, this document will outline the general facts regarding the state of ***global*** climate change, followed by data specific to the Great Lakes region.

General Facts on the State of Global Climate Change

- Warming is occurring in most regions across the globe and is largest at high latitudes in the Northern Hemisphere (Hansen *et al.* 2005, IPCC 2007a).

- Globally, temperatures are increasing and the current rapid warming has no precedent in the human experience. In the last 100 years, global surface temperatures have risen an average 1.33° F (0.74°C). More than 20% of this change has occurred within the last 10 years, with eleven of the last twelve years ranking among the twelve warmest years on record (IPCC 2007a).

- Global temperatures are projected to increase in the future. The warming trend is expected to continue at least through the next century with temperatures up to 11.5°F (6.4ºC) higher by the end of the 21st century (IPCC 2007a).

- Atmospheric carbon dioxide and methane (two major greenhouse gases) have increased by 32% and 147%, respectively, since the beginning of the industrial era (1750). The concentration of CO_2 is now higher than it has been in over 650,000 years (IPCC 2007a).

- Scientific evidence shows that major and widespread climate changes have occurred with startling speed. For example, roughly half the north Atlantic warming during the last 20,000 years was achieved in only a decade, and it was accompanied by significant climatic changes across most of the globe (NRC 2002).

- There have been previous episodes of climate change over the last 40 million years. These episodes have consisted of rapid temperature changes correlating to atmospheric CO_2 changes. The normal behavior in major climate transitions is instability, erratic temperature behavior, and carbon dioxide changes. (Montañez *et al.* 2007; IPCC 2007a).

- Snow cover in the northern hemisphere has declined about 5% over the past 30 years (UCS 2006).

- Freezing altitude has risen in every major mountain chain (UCS 2006).

- In September 2005, the sea-ice extent in the Northern Hemisphere was the lowest recorded since satellite observations began in the 1970s (UK CRU 2005).

- Data and models both show that abrupt climate change during the last major climatic cooling 13,000 years ago originated through natural changes in ocean temperature currents in response to small changes in the hydrologic cycle (Clark *et al.* 2002, Wohlforth 2004).

- Anticipated global warming over the next few centuries causes uncertainty over the stability of the North Atlantic Ocean circulation, including the Gulf Stream (NRC 2002).

- The rate of warming averaged between 1956-2005 (0.13°C per decade) is nearly twice that for the period between 1906–2005 (0.0074°C per decade) (IPCC 2007a).

- The frequency of heavy precipitation events increased over most land areas during the past century, consistent with warming and observed increases of atmospheric water vapor (IPCC 2007a).

- Paleoclimate records indicate that most of the Greenland ice sheet will melt if temperature rises another 2^o-3^o C (Church and Gregory 2001, Hansen 2005) and sea level will rise roughly 7 m (23 ft) if the Greenland ice sheet disintegrates completely (IPCC 2007a).

- Globally, individual species favoring cool climates are shifting their ranges up elevation and towards higher latitudes, and warm-adapted communities are expanding (Watson *et al.* 1997, Parmesan 2006).

- Analysis of changes in phenology (*the scientific study of periodic biological phenomena, such as flowering, breeding, and migration, in relation to climatic changes*) and range of over 1500 species globally show highly significant, nonrandom patterns of change in accord with observed climate warming in the 20^{th} century, indicating a very high confidence (>95%) in a global climate change fingerprint. Species ranges shifted approximately 6 km (4 mi) toward the poles per decade, and spring events came more than 2 days earlier per decade (Parmesan and Yohe 2003; Wohlforth 2004).

Climate Change Impacts in the U.S. Great Lakes Region

I. Temperature Changes

What scientists know…

- The northern Midwest, including the upper Great Lakes region, has warmed by almost 4°F (2°C) in the 20^{th} century (NAST 2000).

- Based on historical records, extreme heat events are occurring more frequently in the Great Lakes region (NAST 2000, Wuebbles *et al.* 2003).

- Data for Lakes Michigan, Huron and Superior show that summer water temperatures are rising. Lake Superior's summer surface water temperatures have increased by 4.5°F (2.5°C) over the last 27 years, a rate approximately double the rate that the air temperatures have risen during the same period (Austin and Colman 2007).

- Two-thirds of the winters over the past 15 years in the Midwest have had temperatures above the long-term historical winter average. The last spring frost is coming earlier and the first autumn frost is coming later (Kling *et al.* 2003, Wuebbles and Hayhoe 2003).

What scientists think they know…

- Climatic model predictions consistently indicate warming in the region (Kling *et al.* 2003, Wuebbles *et al.* 2003).

What scientists think is likely…

- Warming is expected to vary across the Midwest. Different models and scenarios show different patterns of warming, with one model showing an increased warming at higher latitudes, and another showing more warming at lower latitudes (Wuebbles *et al.* 2003).

- Based on climate model predictions, summer temperatures in the Great Lakes region are projected to rise by at least 5°F (3˚C), and as much as 20° F (11˚C) by 2100. Depending on the model and the scenario (high, mid-range or low carbon emission predictions), the projected temperature changes vary (Kling *et al.* 2003, Wuebbles *et al.* 2003.

- Summer temperature changes are likely to show the greatest increase in the southern and western part of the Midwest (Wuebbles *et al.* 2003).

III. Water Cycle Changes (including ice)

What scientists know…

- Ice around the Great Lakes and tributary streams is declining and melting earlier (Robertson *et al.* 1992, Anderson *et al.* 1996, Magnuson *et al.* 2000, Austin and Colman 2007).

- The timing of Lake Superior's summer overturn over the past 27 years is now two weeks earlier than earlier records. On average the date of the summer of overturn has been half a day earlier each year (Austin and Colman 2007).

- Warmer temperatures and reduced lake ice cover and duration of cover will cause an increase in evaporation. (Lofgren *et al.* 2002, Wuebbles *et al.* 2003).

- Based on historical records, winter precipitation is becoming more variable than summer precipitation (Wuebbles *et al.* 2003).

What scientists think they know…

- Declines in lake winter ice are expected to continue (Wuebbles *et al.* 2003).

What scientists think is likely…

- Winter precipitation is expected to increase in the Midwest. Summer precipitation is expected to stay the same or decrease. (Wuebbles *et al.* 2003).

- The duration of winter ice will be shorter in the Great Lakes. Warming temperatures will cause earlier ice melt and change stream peak flow, potentially increasing flood risk from spring rainfall (Kling *et al.* 2003).

- Warmer temperatures and accompanying increase in evaporation will reduce lake water levels (Lofgren *et al.* 2002).

- From 2030 to 2090, Lake Superior may experience 0.22 to 0.43 m (9-17 in) drop in level (Lofgren *et al.* 2002).

- Based on historical records, at the current rate of winter ice decline, Lake Superior is expected to be ice-free during the winter in three decades (Austin and Colman 2007).

- Groundwater levels may decrease. Models show some decreases in aquifers and an expansion of dewatered areas (Lofgren *et al.* 2002).

- The Great Lakes region will likely grow drier overall. Any increases in precipitation will likely be counterbalanced by increased evaporation due to temperature increases (Kling *et al.* 2003).

- Intense short-duration rain storms will occasionally break periods of drought (UCS 2003).

III. Impacts to Vegetation

What scientists know…

- The growing season has been expanding and spring arrives sooner. The average length of winter freeze has been decreasing, with frost days declining in the U.S. The first freeze occurring later and last freeze occurring earlier has expanded the growing season (Wuebbles *et al.* 2003).

- Increasing levels of carbon dioxide affect the physiology of vegetation (Watson *et al.* 1997).

- Cool adapted tree species, such as sugar maple and birch, are projected to have smaller habitat in the northeastern U.S., shifting largely to Canada. Oaks, hickories, and pines may see an expansion of potential habitats, although expansion may be limited by soil and seed dispersal (Watson *et al.* 1997, USDA 2001, Parmesan 2006).

What scientists think they know…

- Increasing carbon dioxide levels could increase the productivity of trees and the efficiency with which they use nitrogen (Watson *et al.* 1997).

- Warming temperatures increase problems related to insects and disease. Because insects and pathogens have shorter life spans than most forest vegetation, they can respond more rapidly to climate change. A longer growing season may mean that more generations of pests can attack vegetation, while a shorter and warmer winter will mean more successful over-wintering for pests. If vegetation has been stressed by drought or fire, it is also more susceptible to disease and infestation (Watson *et al.* 1996, Winnett 1998, USDA 2001, Hayhoe *et al.* 2007).

- Wild rice is likely to be adversely affected. Deep or flooding waters in the early spring could delay germination of seed, leading to crop failures. Lower water levels late in summer could cause wild rice stalks to break under the weight of the fruithead or could make rice beds inaccessible to harvesters. Extended droughts could lead to more competition with other shallow water species (NAST 2000).

- Increased variability of temperature and precipitation will be harmful to vegetation and could cause diebacks. Climate change models predict higher temperature maxima and more extreme precipitation events. As plants rely on specific ranges of temperature and precipitation, longer droughts, more flooding events and heat waves outside of their normal range will stress them. In addition, winters with warm snaps may cause trees and other vegetation to come out of dormancy, which increases their vulnerability to further cold temperatures (Winnett 1998, USDA 2001).

- Future species migrations will differ from the past due to habitat loss and fragmentation, reducing the natural system's ability to respond to global change. In the past, species have migrated through intact forests. With human development, there are fewer forested sites and individuals within a population. This will make migration of species adapting to temperature and precipitation changes more difficult (Iverson *et al.* 2004).

- Forest species composition will change. Bayfield Peninsula (Wisconsin, near Apostle Islands NL) forest composition is modeled to respond to a 5°C (9°F) increase in annual temperature by changing from a northern hardwood/boreal mix to more southern species (He *et al.* 2002). Paper birch habitat is modeled to virtually disappear from the area under some greenhouse gas scenarios (Prasad 1999).

- Increased water temperatures enhance biological productivity, which decreases dissolved oxygen, and could increase the growth of undesirable species, such as algae blooms (Poff *et al.* 2002).

What scientists think is likely…

- Shorter winters and warming temperatures may lead to invasive species, pests, and pathogens and cause redistribution of trees species and significant alternation of ecosystems (Iverson and Prasad 2002, Wuebbles *et al.* 2003).

- Predicting the rate of forest composition change has proven difficult, although some species will not easily adapt if climate change occurs as rapidly as predicted (Thompson *et al.* 1998, Wuebbles *et al.* 2003).

- Warmer temperatures may exacerbate the effects of ozone on forest growth (Watson *et al.* 1997, USDA 2001).

IV. Impacts to Wildlife

What scientists know…

- Under either forest expansion or dieback, relative mixtures of species in forest communities will change. This may cause some species to be at risk. Greater rates of change are associated with greater disequilibrium between the habitat needs of the species and its physical realities (i.e., temperature and precipitation) (Watson *et al.* 1997, Parmesan and Yohe 2003).

- Bird species migration timing and range is changing due to climate change (USGCRP 1996).

- Changes in climate are having significant effects on breeding and winter distribution of birds in North America (Watson *et al.* 1997).

What scientists think they know…

- Distribution of fish will change according to the temperature of water. Warm water fish populations will expand northward, while cold water fish populations will decrease (Wuebbles *et al.* 2003).

- Warmer temperatures will increase the length of summer stratification in lakes in the Great Lakes region, creating deep water, oxygen-depleted areas. This change will negatively impact cold water fish in the lakes (Lehman 2002, Kling *et al.* 2003).

- As spring arrives earlier, mosquitoes and black flies will begin hatching earlier in the season and may take longer to die off as winters become shorter. (Reither 2001).

- Earlier springs and later winters may disrupt the timing between lifecycles of predators and prey (Parmesan 2006).

- In Michigan, one study has shown that some species of migratory birds are arriving significantly earlier than in the past. Although these species appear capable of adapting, they rely heavily on specific vegetation. If the vegetation cannot respond to the same changes, then bird communities will be impacted (USGCRP 1996).

- Increasing temperatures and potential storminess will disrupt the shallow waters where many fish, including the whitefish, spawn. These changes will threaten population levels of native fish (Poff *et al*. 2002).

What scientists think is likely…

- National parks may not be able to meet their mandate of protecting current biodiversity within park boundaries for mammals. Park wildlife, able to move northward or to higher elevation to avoid global warming impacts, may be forced out of the parks and into unprotected habitats (Burns *et al.* 2003).

- Due to vegetation shifts, and thus habitat shifts, parks may experience a shift in mammalian species greater than anything documented in the geologic record. This prediction is based on the idea that species will change location as a group and is debatable. However, several researchers have concluded that rapid changes on the order of 20 to 50 years are possible (Burns *et al.* 2003).

- As lake temperatures increase and the ecosystem is stressed by changing climatic conditions, the number of exotic species, such as zebra mussels and sea lamprey, will likely increase. Zebra mussels add to increased productivity in lakes by out-competing native species and increasing water clarity that leads to accelerated algae growth (Poff *et al.* 2002).

- Specific changes in mammal populations and movements may be hard to predict due to the complexity of their interactions with the environment and the rapid pace of change that is expected (Burns *et al.* 2003).

V. Disturbance and Landscape Modification

What scientists know…

- Changing runoff patterns result in changing stream channel erosion and deposition patterns (Pruski and Nearing 2002).

What scientists think they know…

- Changing precipitation patterns and accompanying lowering of groundwater tables may result in alterations to the drainage pattern, including renewed or accelerated stream bed incision and channel wall erosion, increased sediment transportation and deposition, and drying out of wetlands (Tucker and Slingerland 1997, Winter 2000).

What scientists think is likely…

- Rising temperatures and earlier springs are likely to increase forest fire hazards, lengthen the fire season, and create larger fires. These changes could increase atmospheric carbon contributions from forests (Watson *et al.* 1997, Winnett 1998, USDA 2001, Westerling *et al.* 2006.

- Fires can cause other disruptions, such as accelerated soil erosion and mass wasting events (Luce 2006).

- Warmer water may result in accelerated biological activity and speed deterioration of submerged cultural resources or expanded anoxic conditions and help preserve the resources, such as sunken ships. The one certainty is that climate change will produce challenges to the preservation of cultural resources that have not been faced previously (Nicholls and Klein 2005).

VI. Impacts Relevant to the Park Experience

- Changes in wildlife composition will impact activities in the parks, such as fishing and bird watching.

- Shoulder seasons will begin and end earlier in the spring and start and continue later in the fall. Opportunities for summer activities may extend longer.

- The winter recreation season is becoming shorter and less reliable.

- Park facilities may be inadequate for new conditions. Recreational infrastructure such as fixed docks and boat ramps may be too high as lake levels decline. Shallow water at docks and anchorages may limit access by deeper-draft boats. Navigational hazards and new sand bars may be exposed. There may be pressure on managers to lengthen or lower docks or dredge shallow areas, and to mark navigational water hazards.

- Storms on land could create hazardous conditions and visitor injuries from falling debris, flooding, vehicle accidents, and mass wasting (i.e., landslides, mud flows, rock falls).

- Warmer waters and longer open water (non-ice) seasons may "open" boating to more people and different kinds of boats. Coupled with the increasing frequency and intensity of severe storms, however, this may lead to increasing issues of visitor safety (e.g., groundings, capsizings, etc.) and the need for more rescues by the managing agencies.

- Shallow lake margins will expose new land which, depending on local conditions, may become new beaches or mud flats.

- Drying of ephemeral wetlands on lake margins may adversely affect the food web that supports sport fish communities, as well as the spawning areas fish depend upon for reproduction. Migratory birds and other wetland-dependent organisms will also likely be impacted.

- Reduced groundwater and stream flows may affect the availability of high quality water to support both park ecosystems and facilities.

- Increasing frequency and intensity of severe storms and floods may also pose threats to historic structures, roads and trails, archeological sites, administrative facilities, and other park resources and infrastructure.

- Increased temperatures could hinder physical activities in the parks, resulting in increased heat exhaustion.

- There may be increased public health risk by the likely expansion of the prevalence and range of Lyme and West Nile Virus (IPCC 2007b). Infections in foods (e.g., fish) could also increase (Patz *et al.* 2000).

- Increased summer temperatures will lead to increased utility expenditures in parks in the summer and, potentially, decreases in the winter.

- Decreasing ice cover could increase the impacts of storminess in the shallow water bays around Lake Superior (Austin and Colman 2007).

- Longer mosquito and black fly seasons will be a nuisance to visitors and may increase the risk of mosquito-borne diseases, such as dengue, yellow fever, and West Nile virus (Patz *et al.* 2000, Reither 2001, IPCC 2007b)

VII. What Parks and Their Partners Can Do About It

Great Lakes national parks and their partners are taking steps toward a larger goal of reducing greenhouse gas emissions and their carbon footprints and preparing for future climate change by:

Educating Staff and the Public

- Incorporating climate change research and information in interpretive and education outreach programming.
- Posting climate change information on park bulletin boards and websites.

- Educating park employees, partners, and visitors about climate change and impacts to park resources through training, displays, and by offering resources for further exploration and knowledge.

- Distributing up-to-date interpretive product (e.g., the Servicewide *Climate Change in National Parks* brochure) and supporting the development of region or park-specific interpretive products on the impacts of climate change.

- Developing articles in park web sites about climate change.

- Developing climate change presentations for local civic organizations, user and partner conferences, etc.

- Incorporating climate change questions and answers in park-based Junior Ranger program.

- Helping visitors make the connection between reducing greenhouse gas emissions and resource stewardship.

- Encouraging visitors to reduce their carbon footprint. (For more resources, please see: http://epa.gov/climatechange/wycd/index.html)

Improving Sustainability and Energy Efficiency

- Using more energy efficient products, such as energy efficient light bulbs and energy-star approved office equipment.

- Encouraging visitors to use public or non-motorized transportation to and around parks. Providing, expanding, encouraging, or investigating a shuttle service alternative for visitors to get to the park or to get around the park.

- Including discussion of climate change in the park Environmental Management System.

- Requesting and holding Climate Friendly Park workshops with the EPA in parks.

- Providing alternative fuels and vehicles, such as bicycles for employees to use during warm weather to commute between buildings and employee shuttles to cut back on single car commuters.

- Converting the park's vehicle and boat fleets to alternative fuels such as hybrid electric cars, biodiesel, or propane. Reducing the number and/or size of park vehicles or boats to maximize efficiency.

- Initiating an energy efficiency program to monitor energy use of buildings and offer guidelines for reducing excess energy consumption.
- Providing recycling options for solid waste that is generated at the park.
- Ensuring “green” design for construction of new or re-modeled buildings.
- Using teleconferences instead of flying to meetings.
- Converting to cleaner energy sources, such as solar or wind generated power (Thompson 2007).
- Establishing an in-park sustainability team and developing sustainability Best Management Practices.

Planning Ahead and Collaborating with Others

- Incorporating anticipated climate change impacts, such as decreases in lake levels and changes in vegetation and wildlife, into management plans.
- Incorporating products and services that address climate change in the development of Comprehensive Interpretive Plans.
- Encouraging research and scientific study in the park units.
- Engaging/enlisting collaborator support (e.g., tribes, nearby agencies, etc.) in discussing climate change.
- Taking inventory of the facilities/boundaries/species within your park that are not prepared for climate change.
- Participating in gateway community sustainability efforts.

Through these efforts, and by identifying other opportunities when they arise, Great Lakes National Parks are fulfilling their goal of modeling sustainable practices. By making an effort to understand the science behind climate change, visitors will be better able to make personal choices regarding their opinions, choices, and their options for reducing their own “carbon footprints.”

VIII. References cited

Anderson, W.L., D.M. Robertson, and J.J. Magnuson. 1996. Evidence of recent warming and El Niño-related variations in ice breakup of Wisconsin lakes. Limnology and Oceanography, **41**: 815-821. Available at http://aslo.org/lo/toc/vol_41/issue_5/0815.pdf (accessed 25 June 2007).

Austin, J.A., and S.M. Colman 2007. Lake Superior summer water temperatures are increasing more rapidly than regional air temperatures: A positive-ice albedo feedback. Geophysical Research Letters **34**: L06604. Abstract available at: http://www.agu.org/pubs/crossref/2007/2006GL029021.shtml (accessed 26 June 2007).

Burns, C. E., K.M. Johnston, and O.J. Schmitz 2003. Global climate change and mammalian species diversity in U.S. National Parks. Proceedings of the National Academy of Sciences of the United States of America.

100(20): 11474-11477. Available at: http://www.pnas.org/cgi/reprint/100/20/11474.pdf (accessed 25 June 2007).

Church, J., and J. S. Gregory. 2001. Changes in sea level *in* Houghton, J. T., Y. Ding, D. J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, C.A Johnson (eds.), Climate Change 2001: The scientific basis. Cambridge University Press, Cambridge, U.K.

Clark, P.U., N.G. Pisias, T.F. Stocker, and A.J. Weaver. 2002. The role of the thermohaline circulation in abrupt climate change. Nature **415**:863-869. Available at: http://www.nature.com/nature/journal/v415/n6874/full/415863a.html.

Hansen, J. 2005. A slippery slope: How much global warming constitutes dangerous anthrogenic interference? Climatic Change **68**: 269-279. Available at: http://www.columbia.edu/~jeh1/hansen_slippery.pdf (accessed 25 June 2007).

Hansen, J., R. Ruedy, M. Sato, and K. Lo. 2005. Global temperature trends: 2005 summation. NASA Goddard Institute for Space Studies (GISS). New York, NY. Available at http://data.giss.nasa.gov/gistemp/2005/ (accessed 26 June 2007).

Hayhoe, K., C. Wake, T. Huntington, L. Luo, M. Schwartz, J. Sheffield, E. Wood, B. Anderson, J. Bradbury, A. DeGaetano, T. Troy, and D. Wolfe. 2007. Past and future changes in climate and hydrological indicators in the US Northeast. Climate Dynamics **28**: 381-407. Abstract available at: http://www.ingentaconnect.com/content/klu/382/2007/00000028/00000004/00000187?crawler=true (accessed 25 June 2007).

He, H.H., D.J. Mladenoff, and E.J. Gustafson. 2002. Study of landscape change under forest harvesting and climate warming-induced fire disturbance. Forest Ecology and Management **155**: 257-270. Available at http://ncrs.fs.fed.us/pubs/jrnl/2002/nc_2002_Hong_001.pdf (accessed 25 June 2007).

IPCC (Intergovernmental Panel on Climate Change). 2007a: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [IPCC, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller, editors.] Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp. Available at http://ipcc-wg1.ucar.edu/wg1/wg1-report.html (accessed 26 June 2007).

IPCC (Intergovernmental Panel on Climate Change). 2007b. Climate Change 2007 - Impacts, Adaptation and Vulnerability: Working Group II contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Climate Change 2007) [Adger, N. *et al.*, editors]. Cambridge University Press, New York. Available at: http://www.ipcc.ch/SPM13apr07.pdf (accessed 3 July 2007).

Iverson, L. R. and A. M. Prasad. 2002. Potential redistribution of trees species habitat under five climate change scenarios in the eastern US. Forest Ecology and Management **155**: 205-222. Available at: http://www.fs.fed.us/ne/newtown_square/publications/other_publishers/OCR/ne_2002_iverson001.pdf (accessed 26 June 2007).

Iverson, L. R., M. W. Schwartz and A. M. Prasad. 2004. Potential colonization of newly available tree-species habitat under climate change: an analysis for five eastern US species. Landscape Ecology **19**: 787-799. Available at: http://www.fs.fed.us/ne/newtown_square/publications/other_publishers/OCR/ne_2004_iverson002.pdf (accessed 26 June 2007).

Kling , G.W., K. Hayhoe, L.B. Johnson, J.J. Magnuson, S. Polasky, S.K. Robinson, B.J. Shuter, M.M. Wander, D.J. Wuebbles, D.R. Zak, R.L. Lindroth, S.C. Moser, and M.L. Wilson. 2003. Confronting climate change in the Great Lakes Region. Union of Concerned Scientists, Cambridge, Massachusetts, and Ecological Society of America, Washington, D.C. Available at http://www.ucsusa.org/assets/documents/global_warming/greatlakes_final.pdf (accessed 26 June 2007).

Lehman, J.T. 2002. Mixing patterns and plankton biomass of the St. Lawrence Great Lakes under climate change scenarios. Journal of Great Lakes Research **28**(4): 583-596. Available at http://www.iaglr.org/jglr/db/view_contents.php?pub_id=1995&mode=view&table=yes&topic_id=48&mode=topic_section&volume=28&issue=4 (accessed 26 June 2007).

Lofgren, B. M., F.H. Quinn, A.H. Clites, R.A. Assel, A.J. Eberhardt, and C.L. Luukkonen. 2002. Evaluation of potential impacts on Great Lakes water resources based on climate scenarios of two global circulation models. Journal of Great Lakes Research **28**(4): 537-554. Abstract available at http://www.glerl.noaa.gov/pubs/fulltext/2002/20020020.pdf (accessed 26 June 2007).

Luce, C.H. 2006. Mass wasting following forest fires: processes at multiple scales. Mass Wasting in Dirsturbed watersheds – Association of Engineering Geologists Shlemon Specialty Conference Abstracts Received. Abstract available at: haneberg.com/watersheds/abstracts.html (accessed 14 August 2007).

Magnuson, J.J., D.M. Robertson, B.J. Benson, R.H. Wynne, D.M. Livingstone, T. Arai, R.A. Assel, R.G. Barry, V. Card, E. Kuusisto, N.G. Granin, T.D. Prowse, K.M. Stewart, and V.S. Vuglinski. 2000. Historical trends in lake and river ice cover in the Northern Hemisphere. Science **289**: 1743-1746. Abstract available at http://www.sciencemag.org/cgi/content/abstract/289/5485/1743 (accessed 26 June 2007).

Montañez, I.P., N.J. Tabor, D. Niemeier, W.A. DiMichele, T.D. Frank, C.R. Fielding, J.L. Isbell, L.P. Birgenheier, and M.C. Rygel. 2007. CO_2-forced climate and vegetation instability during late Paleozoic deglaciation. Science. **315**(5808): 87 – 91. Abstract available at http://www.sciencemag.org/cgi/content/abstract/315/5808/87(accessed 26 June 2007).

National Assessment Synthesis Team (NAST). 2000. Climate change impacts on the United States: the potential consequences of climate variability and change. US Global Change Research Program. Washington DC. Available at http://www.usgcrp.gov/usgcrp/Library/nationalassessment/overview.htm (accessed 26 June 2007).

NRC (National Research Council). 2002. Abrupt climate change, inevitable surprises. National Academy Press, Washington, DC. 244 pp. Available at http://newton.nap.edu/catalog/10136.html#toc (accessed 26 June 2007).

Nicholls, R.J., and F.J.T. Klein. 2005. Climate change and coastal management of Europe's coast *in* F. Allan, U. Forstner, W. Salomons, J. Vermaat, M. Salomons, L. Bouwer, and K. Turner. Managing European coasts – past, present, and future. SpringerLink Berlin. Pages 199-226. Abstract available at: www.springerlink.com/content/j7x86g24370780k0/ (accessed 14 August 2007).

Pruski, F.F., and M.A. Nearing. 2002. Climate-induced changes in erosion during the 21st century for eight U.S. locations. Water Resources Research **38**/12: 1298. Available at: www.agu.org/pubs/crossref/2002/2001WR000493.shtml (accessed 13 August 2007).

Parmesan, C. and G. Yohe. 2003. A globally coherent fingerprint of climate change impacts across natural systems. Nature **421**:37-42. Abstract available at http://www.nature.com/nature/journal/v421/n6918/abs/nature01286.html (accessed 26 June 2007).

Parmesan, C. 2006. Ecological and evolutionary responses to recent climate change. Annual Review of Ecology, Evolution, and Systematics **37**: 637-669. Available at: http://cns.utexas.edu/communications/File/AnnRev_CCimpacts2006.pdf (accessed 26 June 2007).

Patz, J., M. McGeehin, S. Bernard, K. Ebi, P. Epstein, A. Grambsch, D. Gubler, P. Reither, I. Romieu, J. Rose, J. Samet, and J. Trtanj. 2000. The potential health impacts of climate vulnerability and change for the United States: executive summary of the report of the U.S. national assessment. Environmental Health Perspectives **108**/4: 367-376. Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1638004 (accessed 16 July 2007).

Poff, N. L., M.M. Brimson, and J.W. Day, Jr., 2002. Aquatic ecosystems and global climate change: potential impacts on inland freshwater and coastal wetland ecosystems in the United States. Pew Center on Global Climate Change. Available at: http://www.pewclimate.org/docUploads/aquatic%2Epdf (accessed 26 June 2007).

Prasad, A. M. and L. R. Iverson. 2007. A climate change atlas for 80 forest tree species of the eastern United States [database]. Northeastern Research. http://www.nrs.fs.fed.us/atlas/ (accessed 26 June 2007).

Reither, P. 2001. Climate change and mosquito-borne disease. Environmental Health Perspectives **109**: 141-161. Abstract available at: http://www.ncbi.nlm.nih.gov/sites/entrez?cmd=Retrieve&db=PubMed&list_uids=11250812&dopt=Abstract (accessed 26 June 2007).

Robertson, D. M., R.A. Ragotzkie, and J.J. Magnuson. 1992 Lake ice records used to detect historical and future climatic changes. Climatic Change **21**:407-427. Abstract available at: http://www.springerlink.com/content/m7950303747854w7/ (accessed 26 June 2007).

Thompson, J. D., M.D. Flannigan, B.M. Wotton, R. Suffling. 1998. The effects of climate change on landscape diversity: an example in Ontario forests. Environmental Monitoring and Assessment **49**: 213-233. Abstract available at: http://www.ingentaconnect.com/content/klu/emas/1998/00000049/F0020002/00145032 (accessed 26 June 2007).

Tucker, G.E., and R. Slingerland. 1997. Drainage basin responses to climate change. Water Resources Research **33**/8:2031-2047. Available at: www.colorado.edu/geolsci/gtucker/preprints/tuckslingwrr97.pdf (accessed 14 August 2007).

UCS (Union of Concerned Scientists). 2006. Global warming 101: 2005 vies for hottest year on record. Available at http://www.ucsusa.org/global_warming/science/recordtemp2005.html (accessed 26 June 2007).

UK CRU (United Kingdom Climate Research Unit). 2005. Global temperature for 2005: second warmest year on record. Norwich U.K. Available at http://www.cru.uea.ac.uk/cru/press/2005-12-WMO.pdf (accessed 26 June 2007).

USDA (United States Department of Agriculture). 2001. Forests: the potential consequences of climate variability and change. A report of the National Forest assessment group for the U.S. Global Change Research Program. Available at http://www.usgcrp.gov/usgcrp/Library/nationalassessment/forests/forest.pdf (accessed 26 June 2007).

USGCRP (US Global Change Science Research Program). 1996. The ecological effects of global warming on North American birds and butterflies. Overview: Terry Root. Seminar, 22 October 1996. Available at: http://www.usgcrp.gov/usgcrp/seminars/961010DD.html (accessed 26 June 2007).

Watson, R.T., M.C.Zinyowera, and R.H.Moss, editors, 1996. Impacts, adaptations and mitigations of climate change: Scientific-technical analyses. Intergovernmental Panel on Climate Change. New York: Cambridge University Press, Cambridge, UK.

Watson, R.T., M.C.Zinyowera, and R.H.Moss, editors, 1997. Intergovernmental Panel on Climate Change (IPCC). 1998. The regional impacts of climate change: an assessment of vulnerability. Intergovernmental Panel on Climate Change. New York: Cambridge University Press, Cambridge, UK. Cambridge University Press, Cambridge, UK.

Westerling, A. L., H. G. Hidalgo, D. R. Cayan, and T. W. Swetnam. 2006. Warming and earlier spring increases western U.S. forest wildfire activity. SciencExpress 2006(July 6):1-9. Available at: http://www.sciencemag.org/cgi/content/full/313/5789/940 (accessed 27 June 2007).

Winnet, S. M. 1998. Potential effects of climate change on U.S. forests: a review. Climate Research **11**: 39-49. Available at: http://www.int-res.com/articles/cr/11/c011p039.pdf (accessed 26 June 2007).

Winter, T.C. 2000. The vulnerability of wetlands to climate change: a hydrologic landscape perspective. Journal of the American Water Resources Association **35**/2: 305-311. Available at: www.blackwell-synergy.com/doi/abs/10.1111/j.1752-1688.2000.tb04269.x?journalCode=jawr (accessed 14 August 14, 2007).

Wohlforth, Charles. 2004. The whale and the supercomputer. North Point Press. New York. 322 pp.

Wuebbles, D. L. and K. Hayhoe. 2003. Climate Change Projections for the United States Midwest. Mitigation and Adaptation Strategies for Global Change **9**: 335-363. Abstract available at: http://www.springerlink.com/content/k066717671581161/ (accessed 26 June 2007).

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